Plasmasphere Data Assimilation and Comparison with In-Situ Observations

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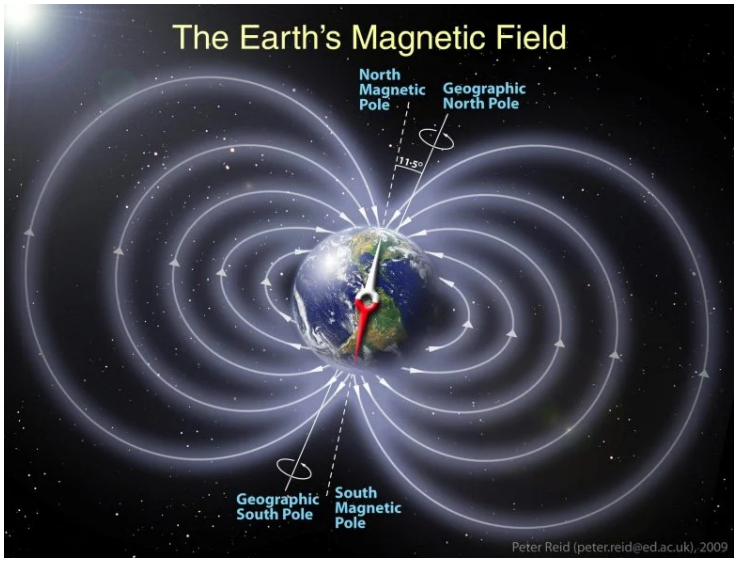
Outline

- Brief introduction to the Earth’s magnetosphere
- The plasmasphere and the radiation belts
- Observations of the plasmasphere
- Modeling and data assimilation approach
- Results
- Conclusion

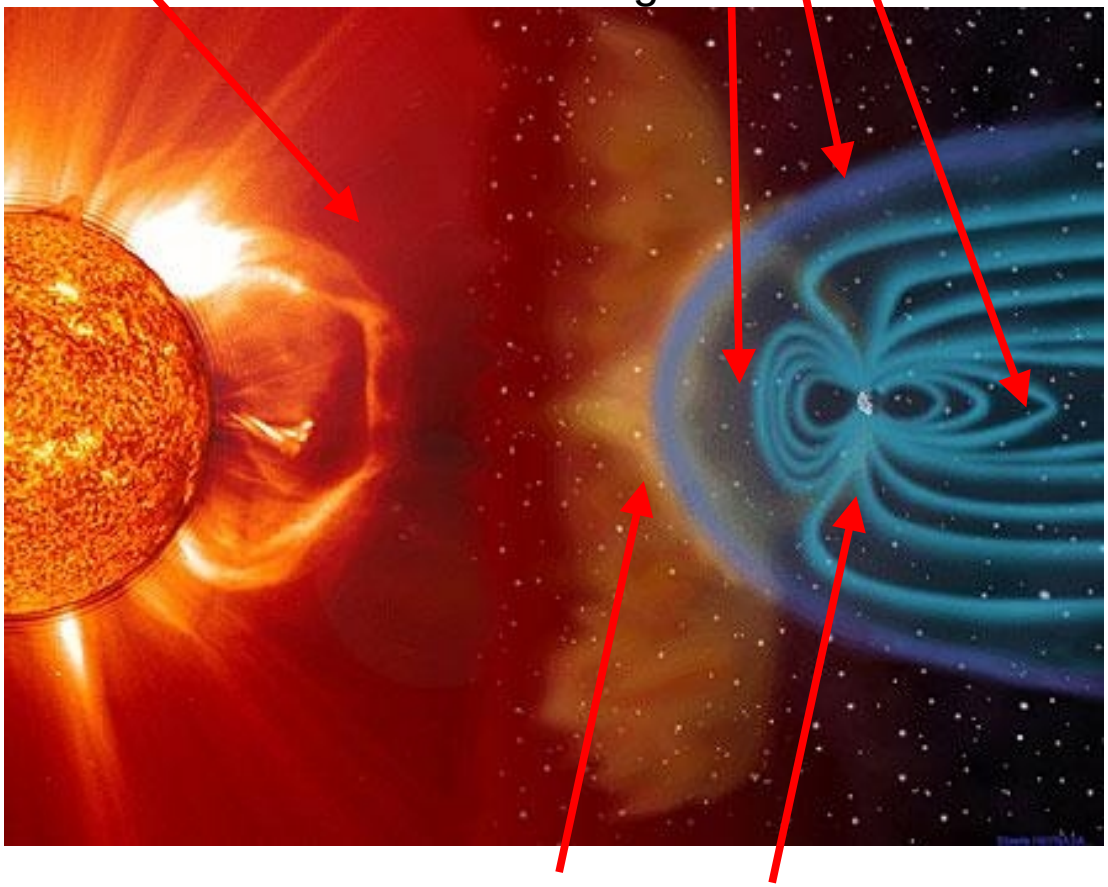
The Earth's Magnetosphere

Approximately a dipole, created in the molten portion of Earth's core



The solar wind: supersonic plasma and magnetic field

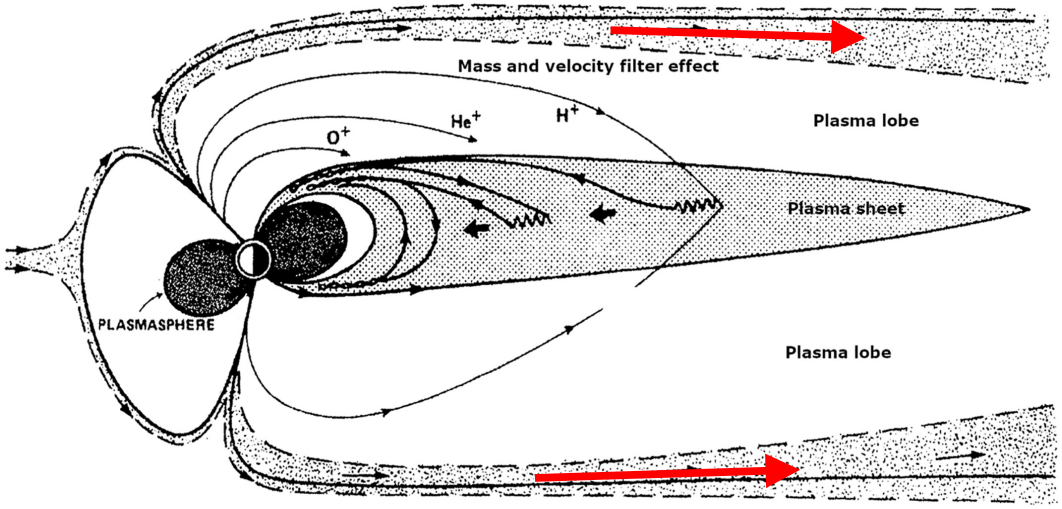
Current systems must exist to support modified magnetic field



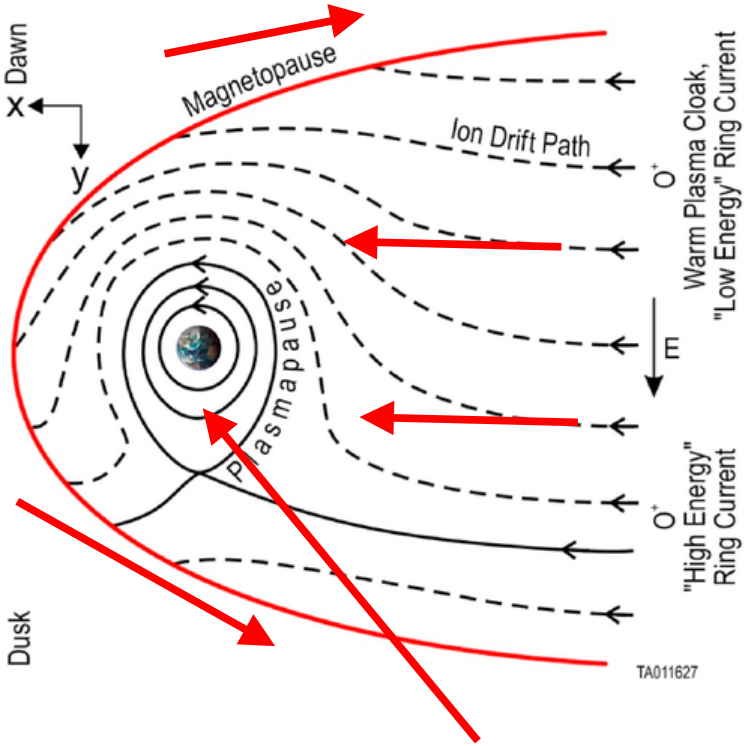
Creates a shock front with a magnetically shielded, largely impenetrable magnetospheric cavity behind it.

Magnetospheric Convection

View from the dusk side



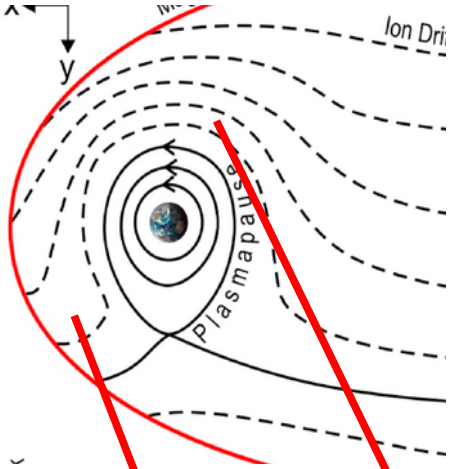
View from the north



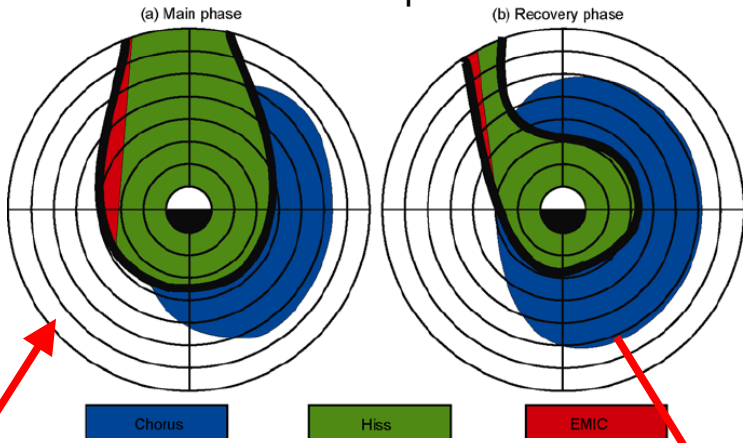
$$\boldsymbol{v}_E = \frac{\boldsymbol{E} \times \boldsymbol{B}}{B^2}$$

Region close to Earth dominated by the Earth's magnetic field which is rotating, dragging along the plasma

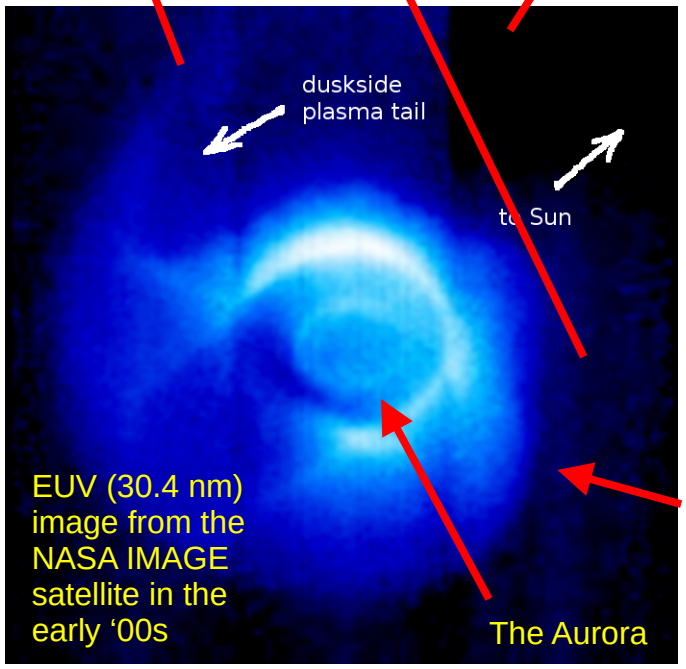
Plasmasphere and Radiation Belts



Different kinds of plasma waves

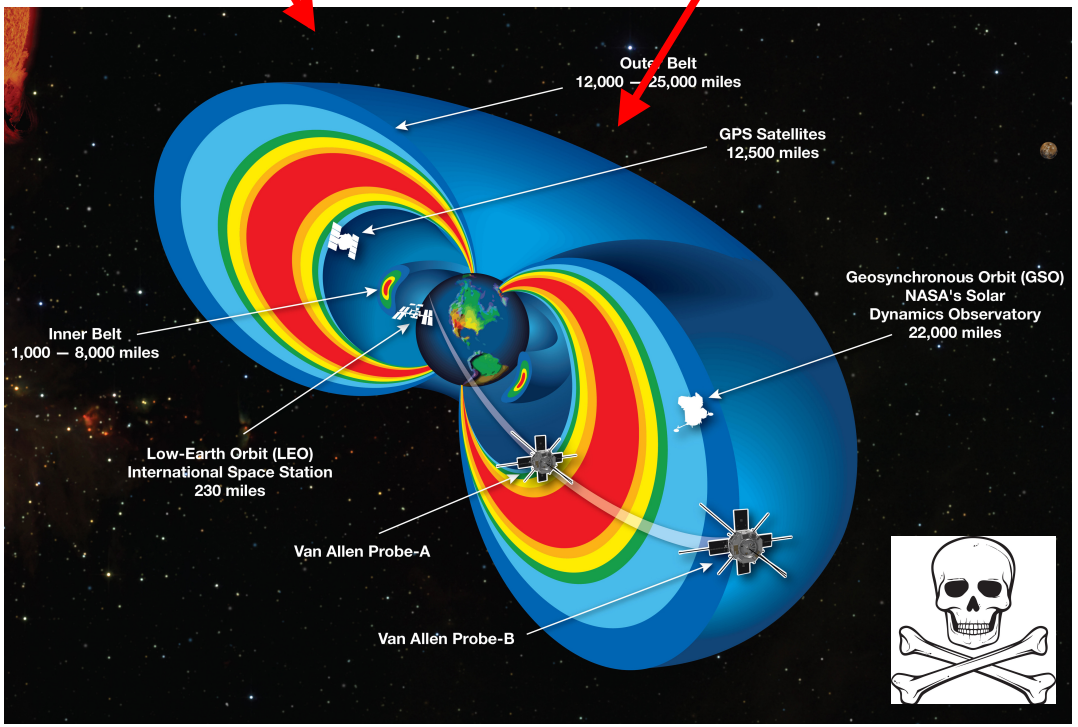


Both very dynamic. Changes in solar wind conditions change size and shape of plasmasphere, and radiation belt fluxes can change by order of magnitudes in minutes/hours



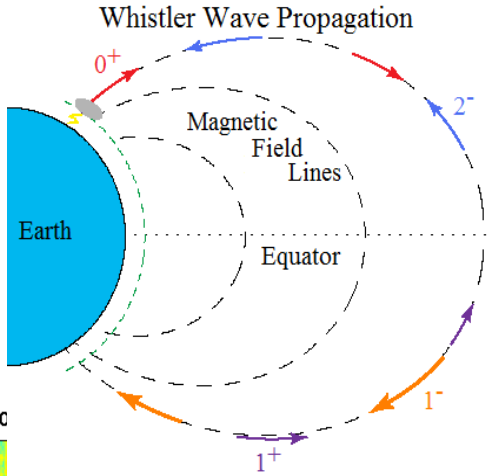
Cold plasma (< 1 eV)

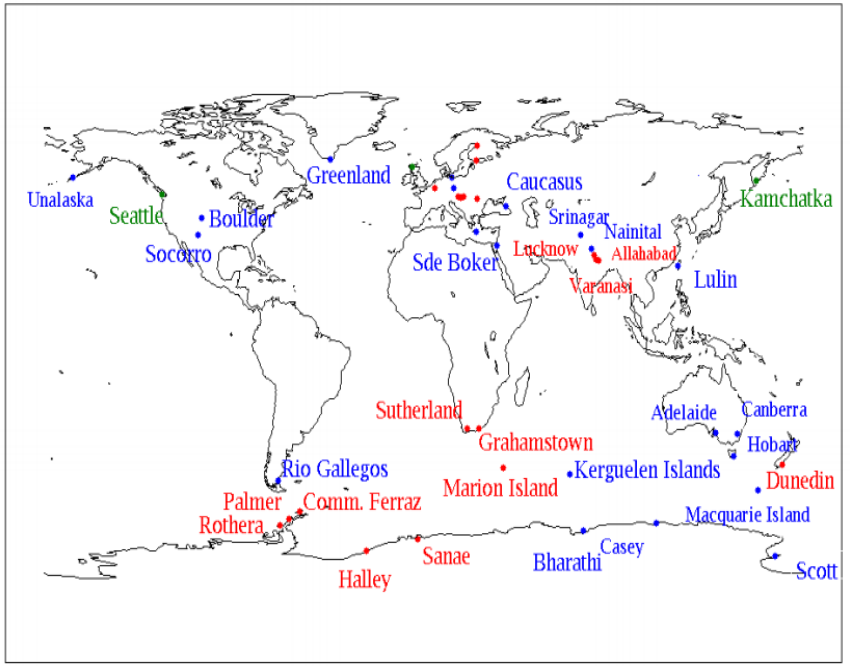
Energetic plasma (keV to MeV)

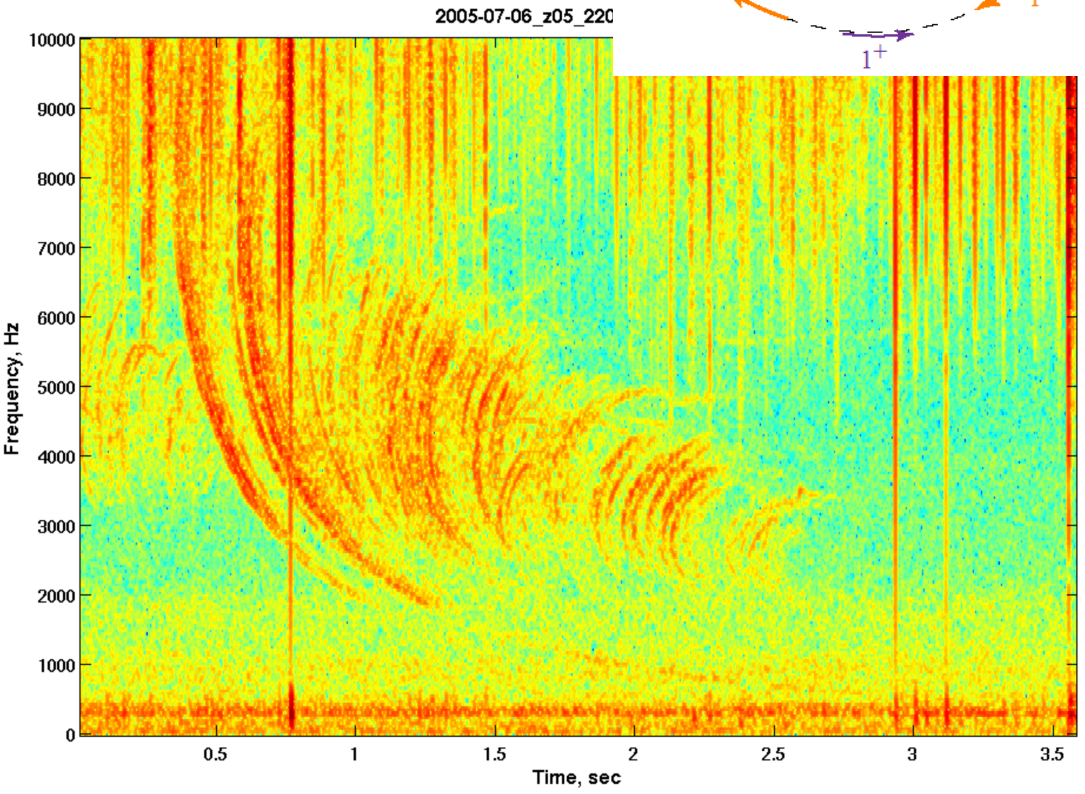


Measuring the Plasmasphere

1) with satellites, e.g. Van Allen Probes (expensive)
2) Whistler waves (very cheap RF instruments)
3) Magnetometers measuring resonances (medium cheap)







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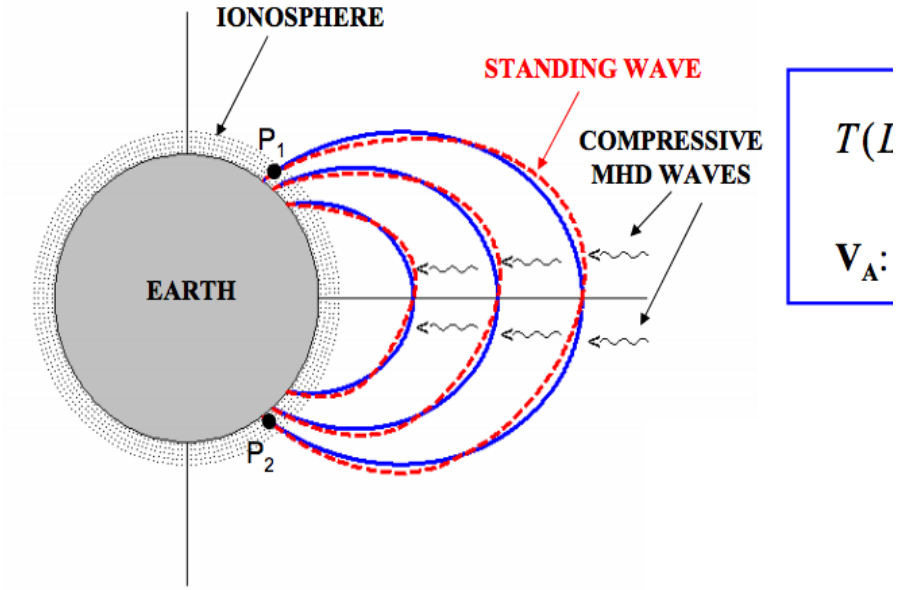

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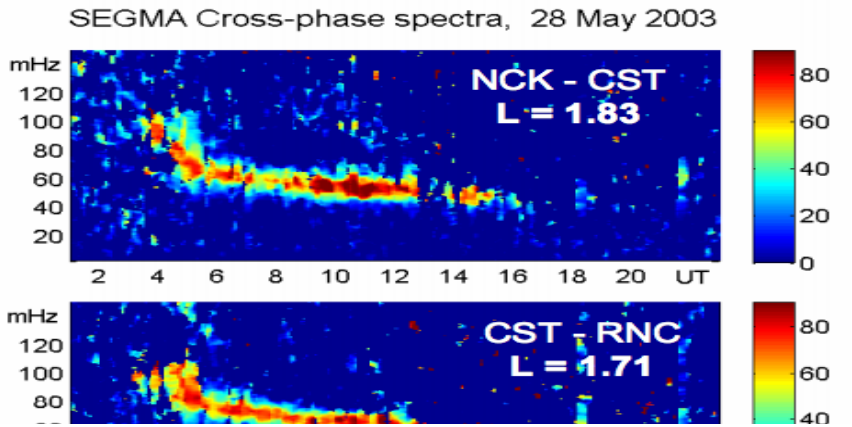
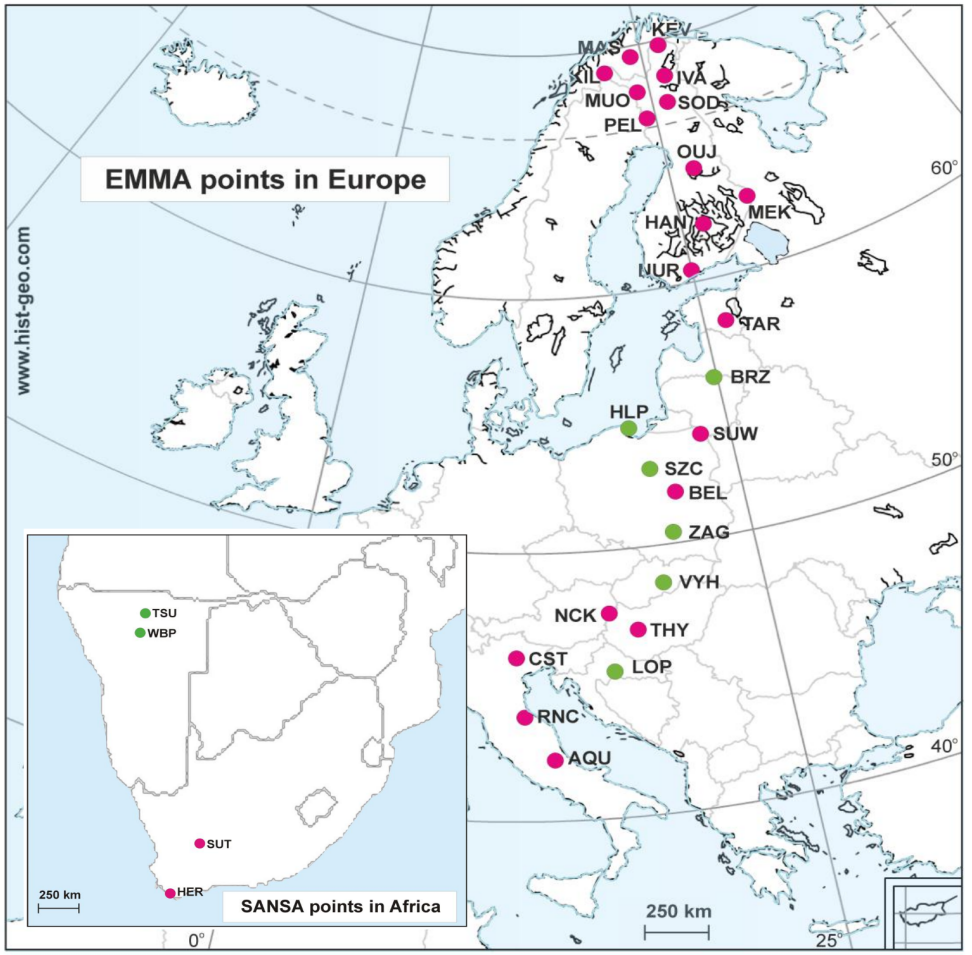




Plasmasphere Model

A simple model of the Plasmasphere will filling, lost, and transport, the Dynamic Global Core Plasma Model (Ober, 1997)

Magnetic field $\vec{B}(\vec{r})$

Electric field $\vec{E}(\vec{r})$

Sunlit

$$F_d = \frac{n_{\mathrm{sat}} - n}{n_{\mathrm{sat}}} F_{\max}$$

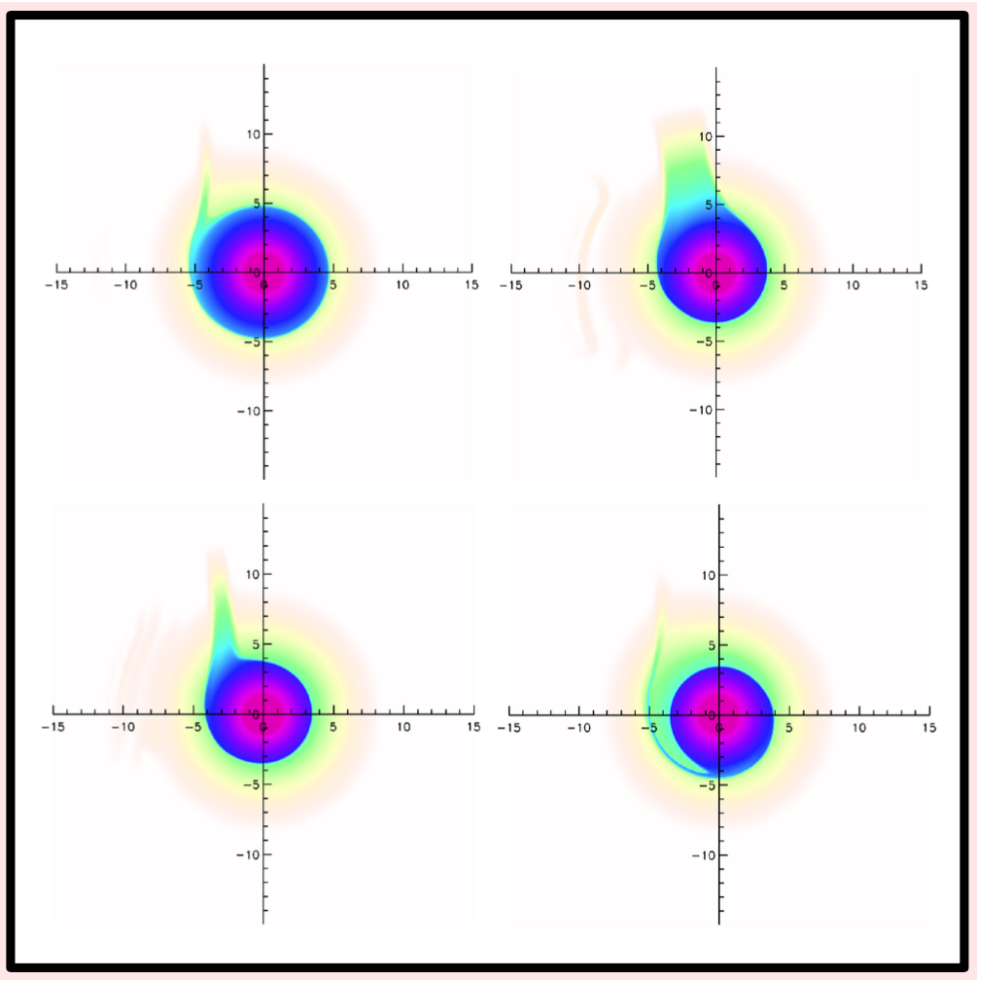
Shadowed

$$F_n = -\frac{N B_i}{\tau}$$

Convection and filling

$$\frac{D_\perp N}{Dt} = \frac{F_N + F_S}{B_i}$$

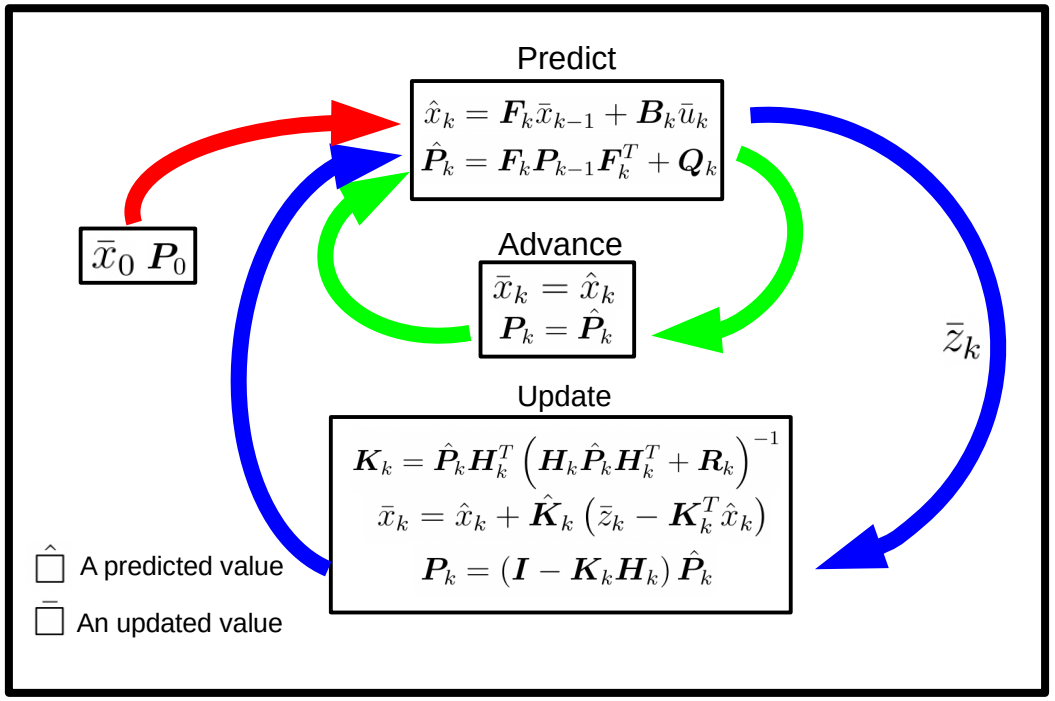
Flux tube content $N(\vec{r})$



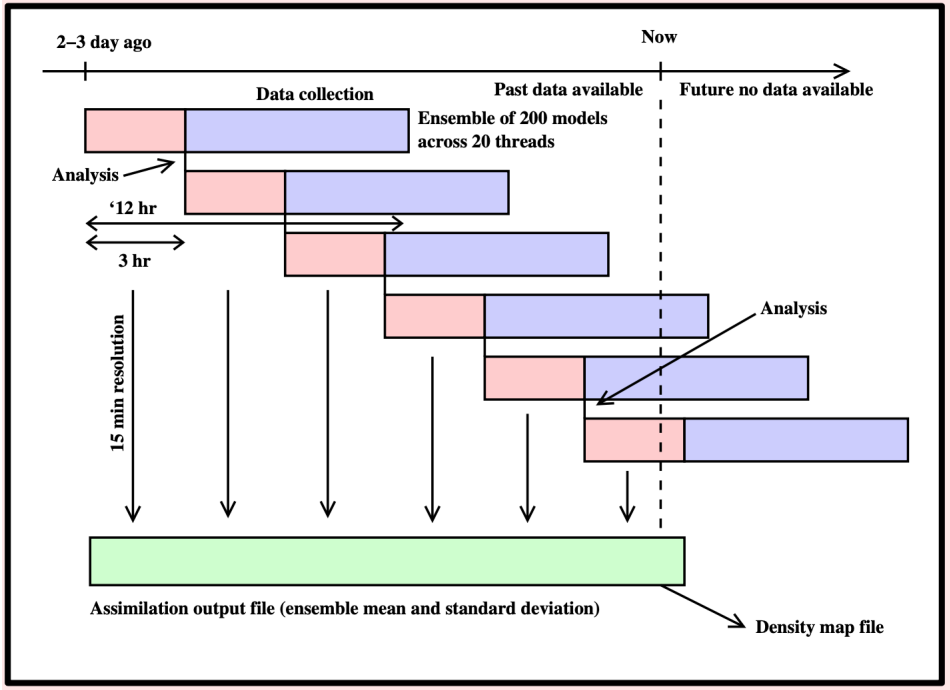
Data Assimilation

The model by itself is ok, but the accuracy can be improved by incorporating observations in a data assimilation framework

Kalman filter

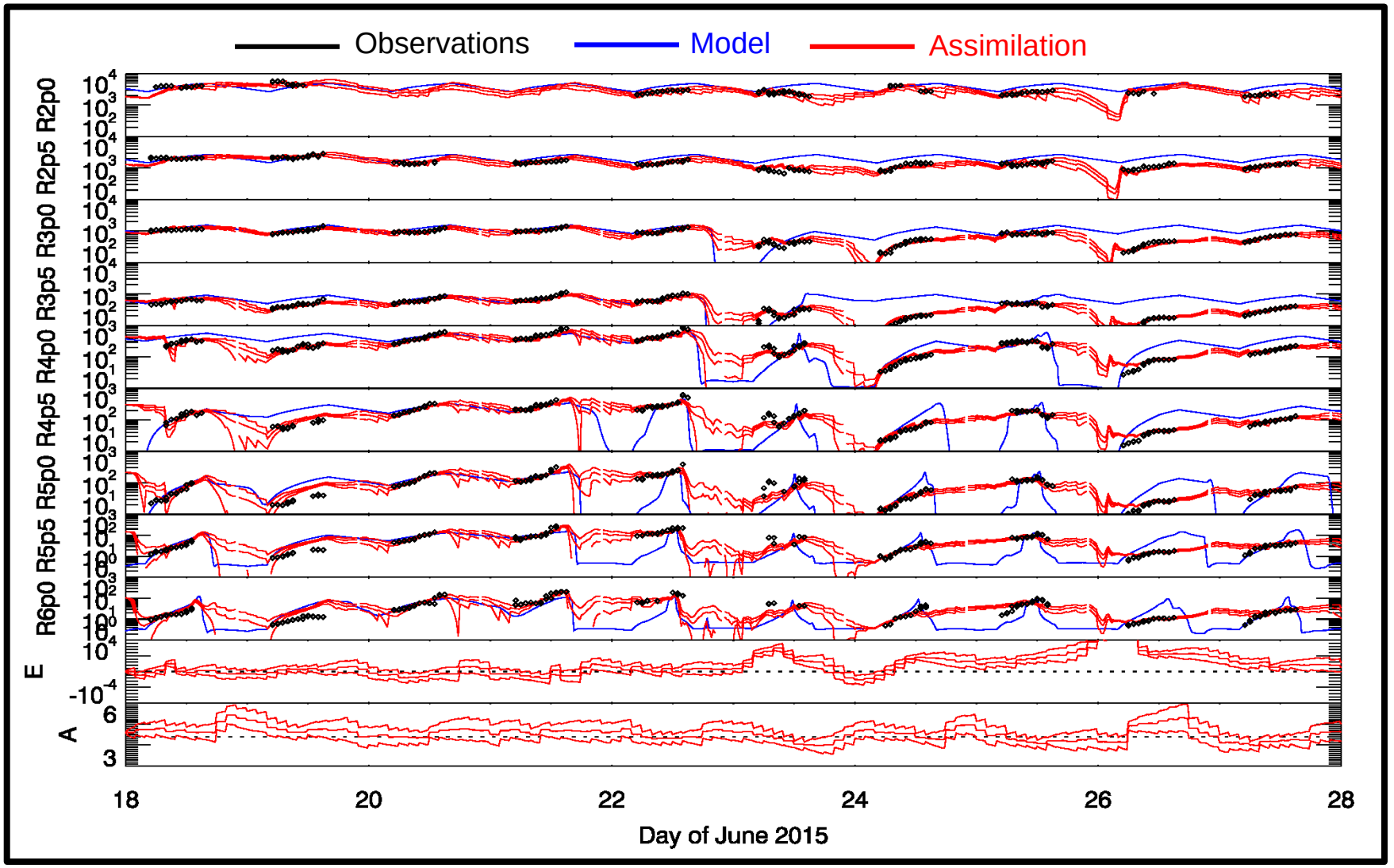


Ensemble Kalman filter which incorporates future observations. This is necessary because observations only constrain the unknown model inputs in the past.



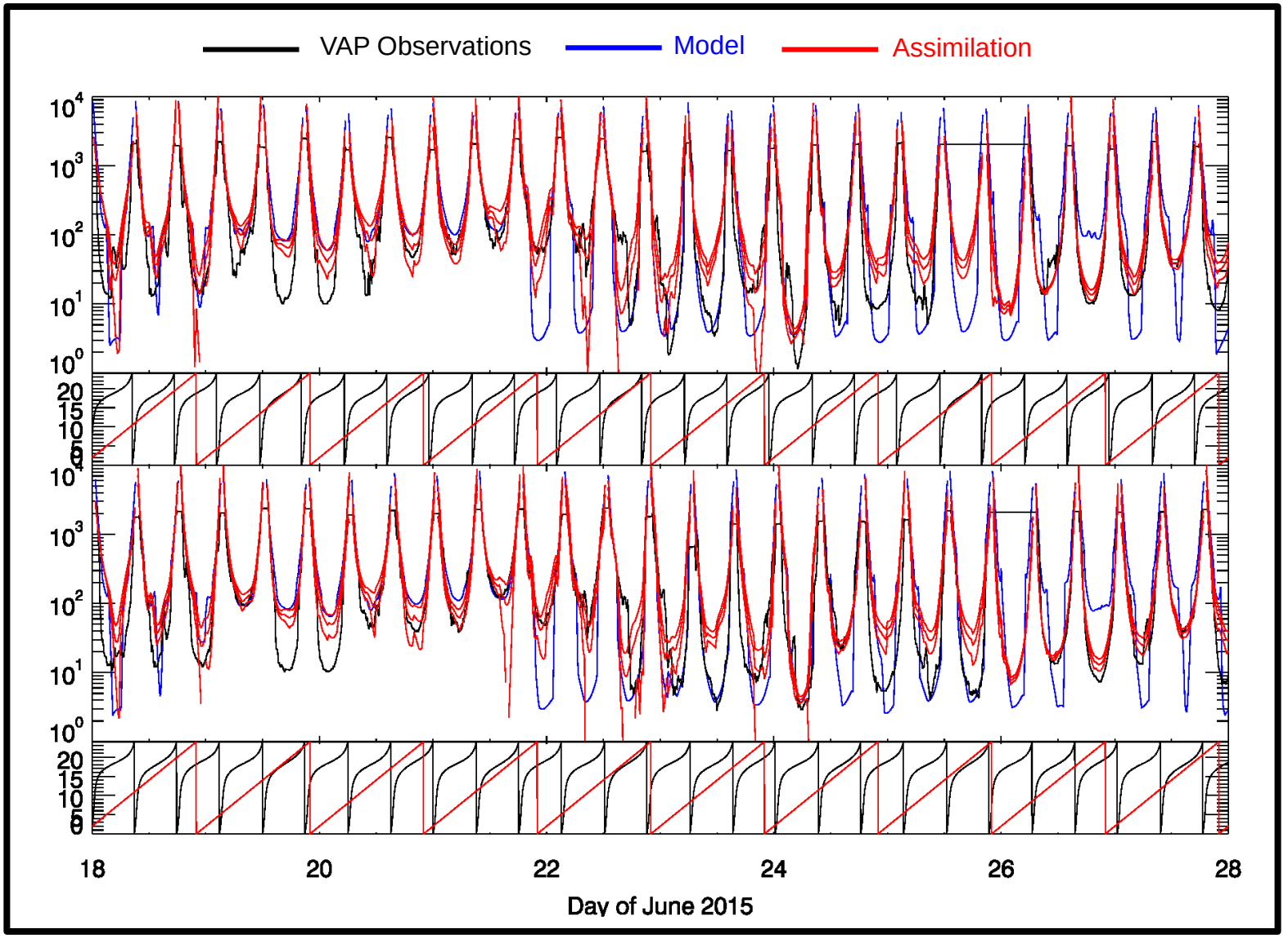
Result

Assimilation output compared with the assimilated observations



Comparison

Assimilation output compared with an independent data set



Conclusion

- The Earth's plasmasphere is an important driver of the wave activity which controls the radiation belts
- Plasmaspheric density can be remotely sensed from ground-based observatories
- We use a modified Ensemble Kalman Filter which constrains past model drivers based on current data (or uses future observations to constrain current model drivers)
- Incorporating these point observations into a data assimilation framework results in more accurate estimate of plasma density, which can be used to produce better radiation belt forecases